MIT International Center for Air Transportation

Distributed Simulation for Evaluating Low Noise ATC Procedures

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Massachusetts Institute of Technology

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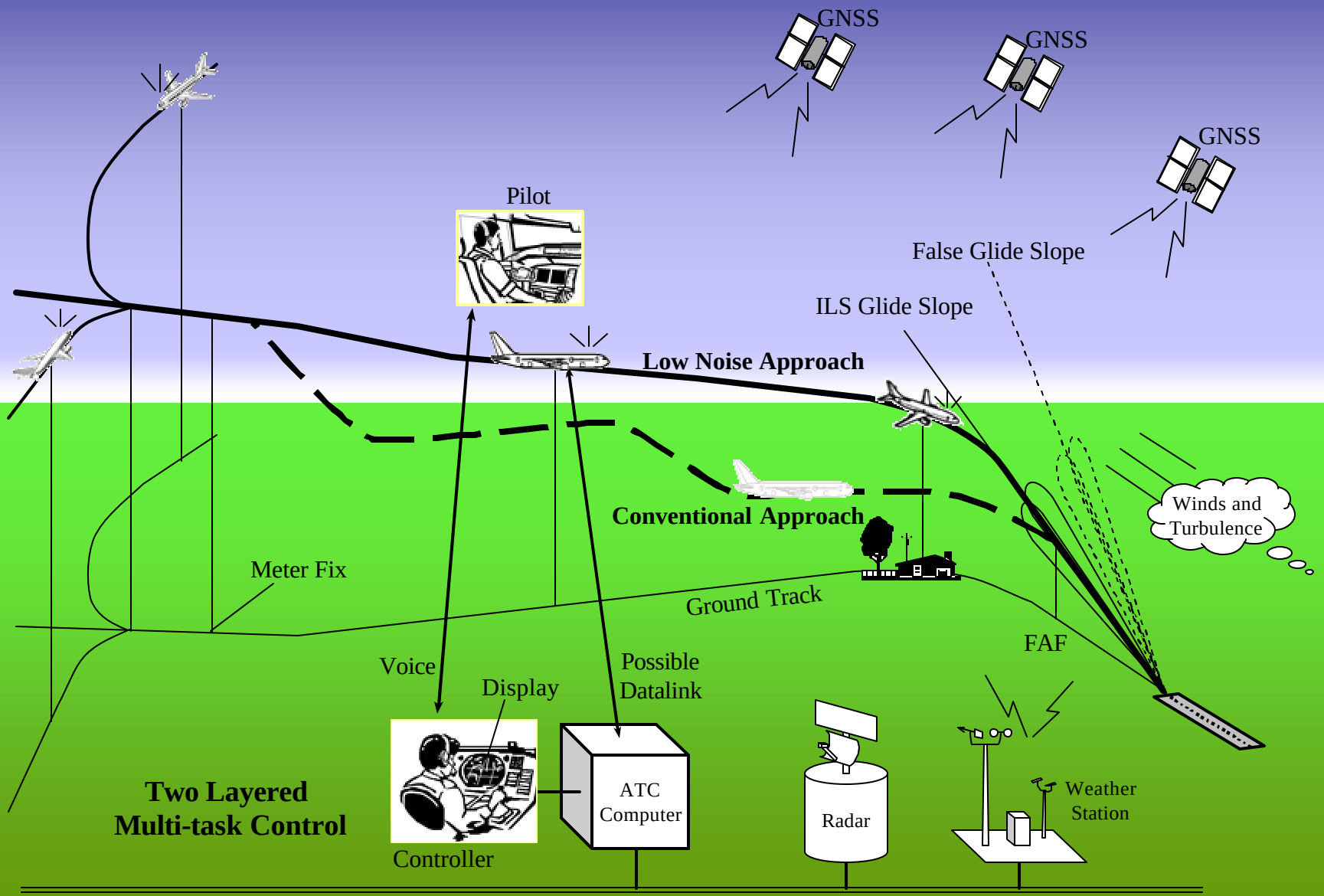
Ohio University, Athens, OH

Louisville International Airport (KSDF)

KSDF is the home of UPS sorting hub, every night there are about 100 UPS jet aircraft arriving at the airport. Four miles north of the airport is down town Louisville. The simulation experiment will be based on approach to runway 17R.

Photo from J.-P. Clarke et al. 2003

Low Noise Approach and ATC Environment



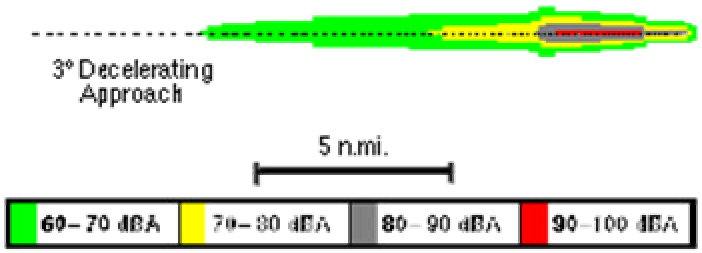
Conventional ILS vs. Low Noise

Conventional ILS Procedure

- Step-down descent
- Capture glide slope from below to avoid false slope
- Level flight at low altitude
  - Requires full power
- Higher noise

Low Noise Approach (LNA)

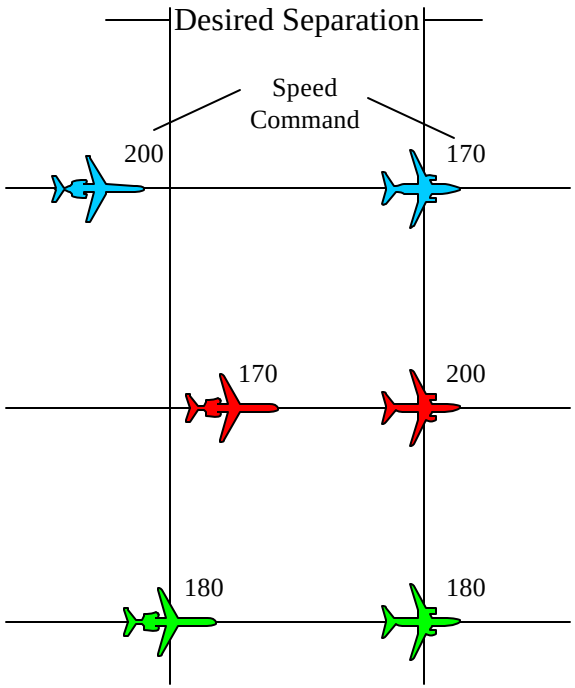
- Continuous descent
- Advanced technology enables capturing glide slope directly
- No level flight at low altitude
  - Use low power or idle
- Delayed flap extension
- Lower noise



Single event noise contours
Source: Clarke, J.-P. & R. J. Hansman

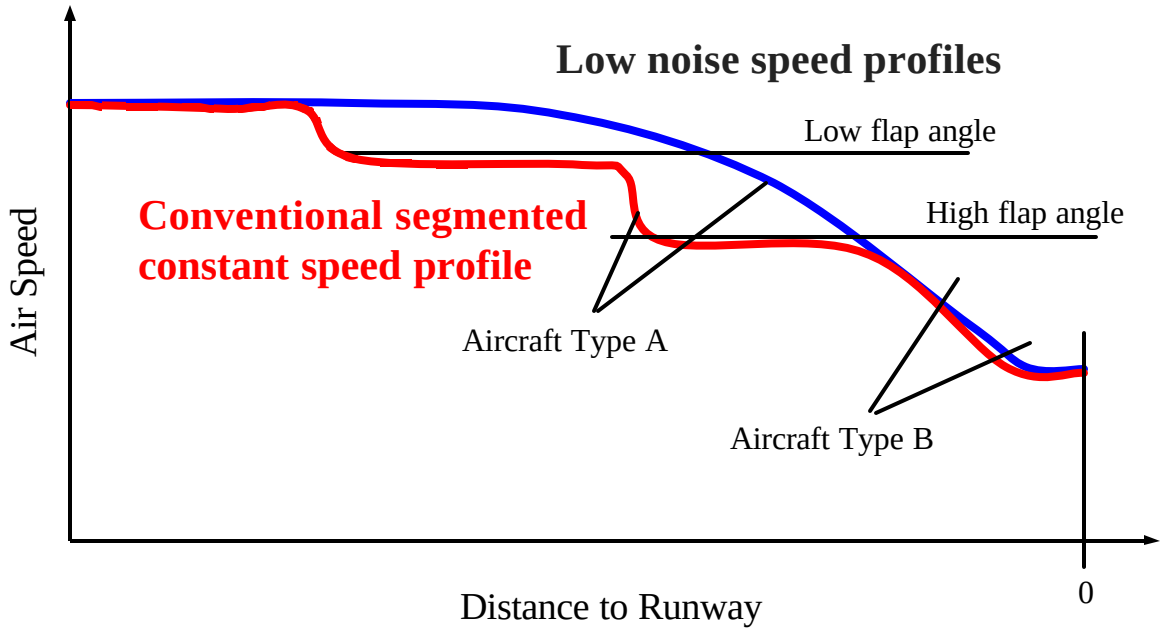
Existing ATC Techniques

- **Primary Objectives of ATC**
  - Maintain safe separation between aircraft
  - Organize and expedite the flow of traffic
- **Maintain Longitudinal Separation**
  - Use speed control to adjust separation
  - Once desired separation is established, place aircraft at same speed
  - No further speed intervention necessary after final approach fix (FAF) when aircraft capture glide slope
- **Results in**
  - Segmented constant speed approach



ATC Issues with Low Noise Approach

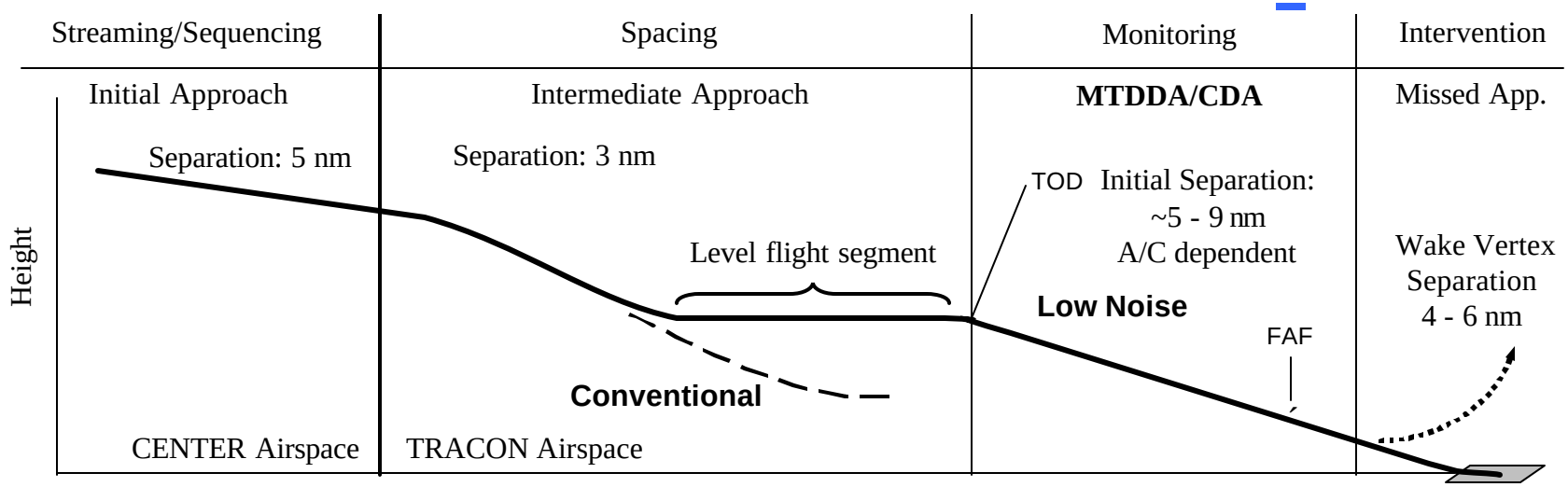
- **Ideal Low Noise Approach**
  - Different aircraft follow different decelerating speed profiles
  - Speed control can no longer be freely applied
- **Controllers no longer able to manually separate aircraft without sacrificing capacity***



*Ho & Clarke, 2001

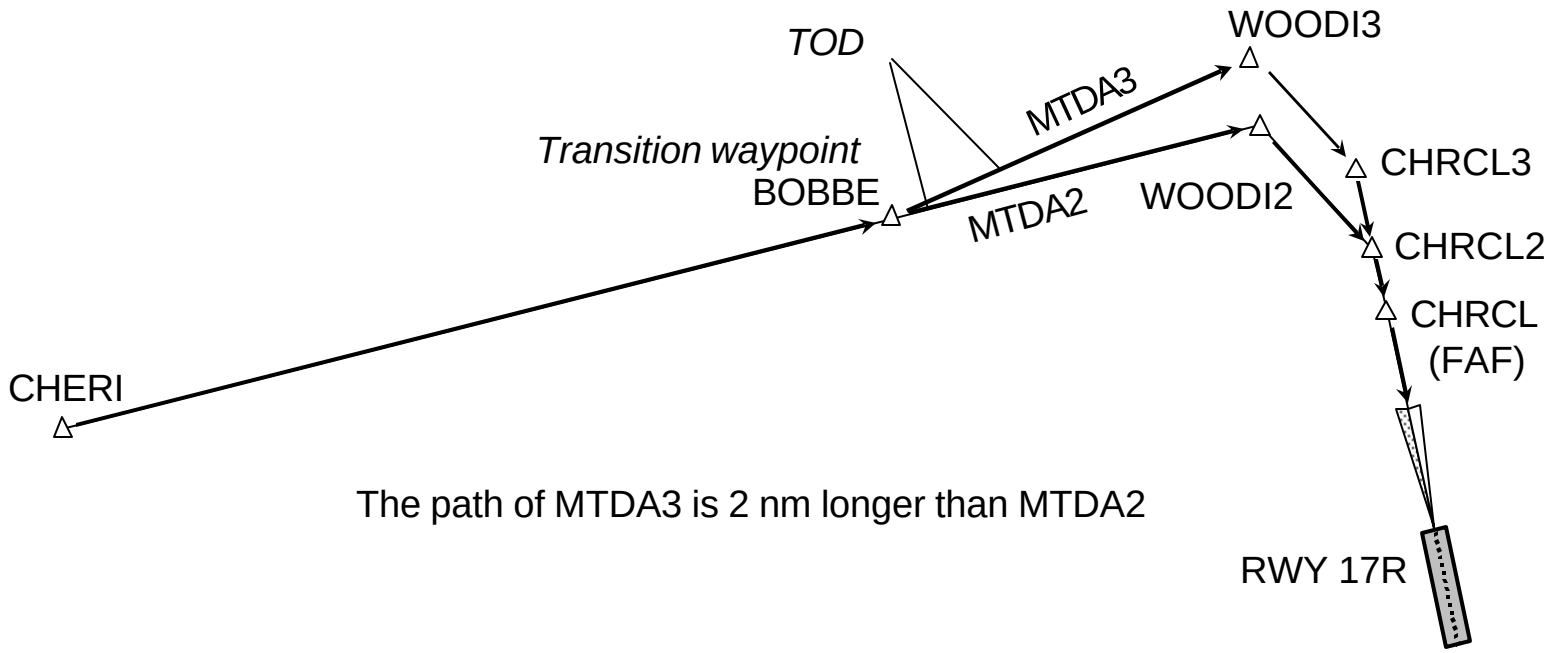
Procedure Design

- **Low Noise Approach with Intermediate Level Flight Segment**
  - Low noise descent starts from level flight at intermediate altitude
  - Free to apply speed control before top-of-descent (TOD)
  - Controller establishes initial separation and initial speed at TOD
  - Preferably no controller intervention after TOD



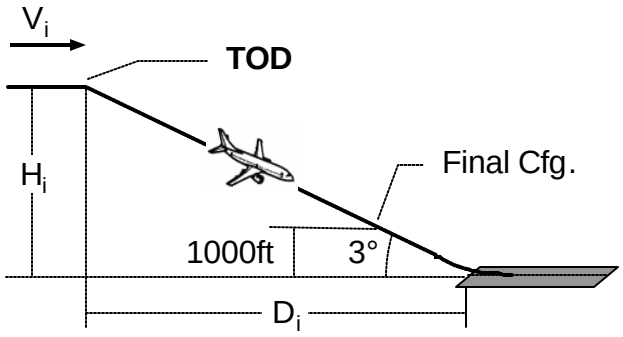
Lateral Flight Path Stretching

- **Provide Additional Separation Leverage after TOD**
  - Nominal lateral flight path is the shortest to save time and fuel
  - Predefined stretched flight paths provide means to delay aircraft
  - Stretched flight path selected by pilot via CDU upon receiving vectoring clearance from controller



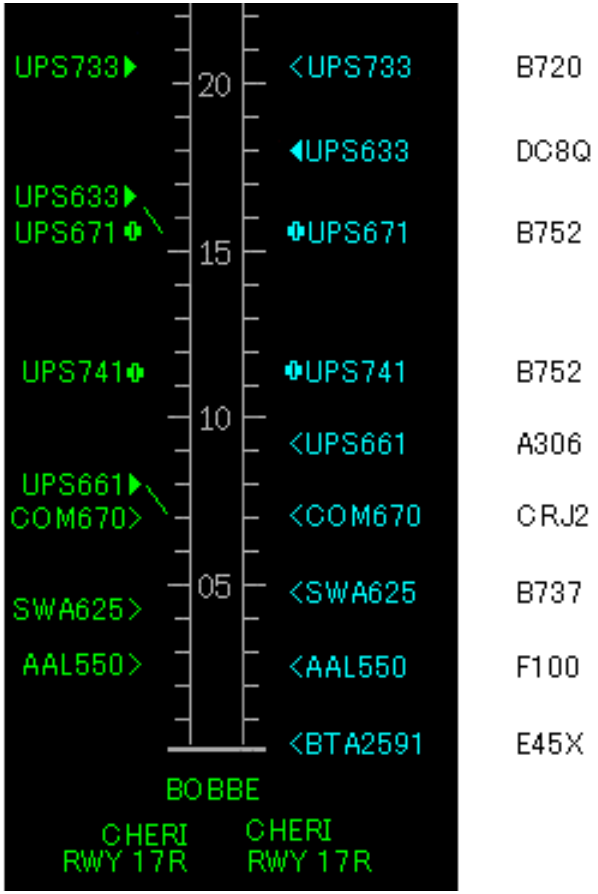
Low Noise Descent Segment

- **It Determines Initial Separation and Initial Speed at TOD**
  - Trajectory prediction, wake vortex spacing, and safety buffer
- **Ideal Profile Optimized for Noise Impact**
  - Different for different aircraft type, weight and wind estimates
  - Possible high variation due to operation uncertainty
- **More Structured, Robust and Stable Profile**
  - Use low power rather than idle
  - Restrict speed during the first half of the descent
  - To reduce complexity and improve conformance monitoring



Automation Design – Time Line

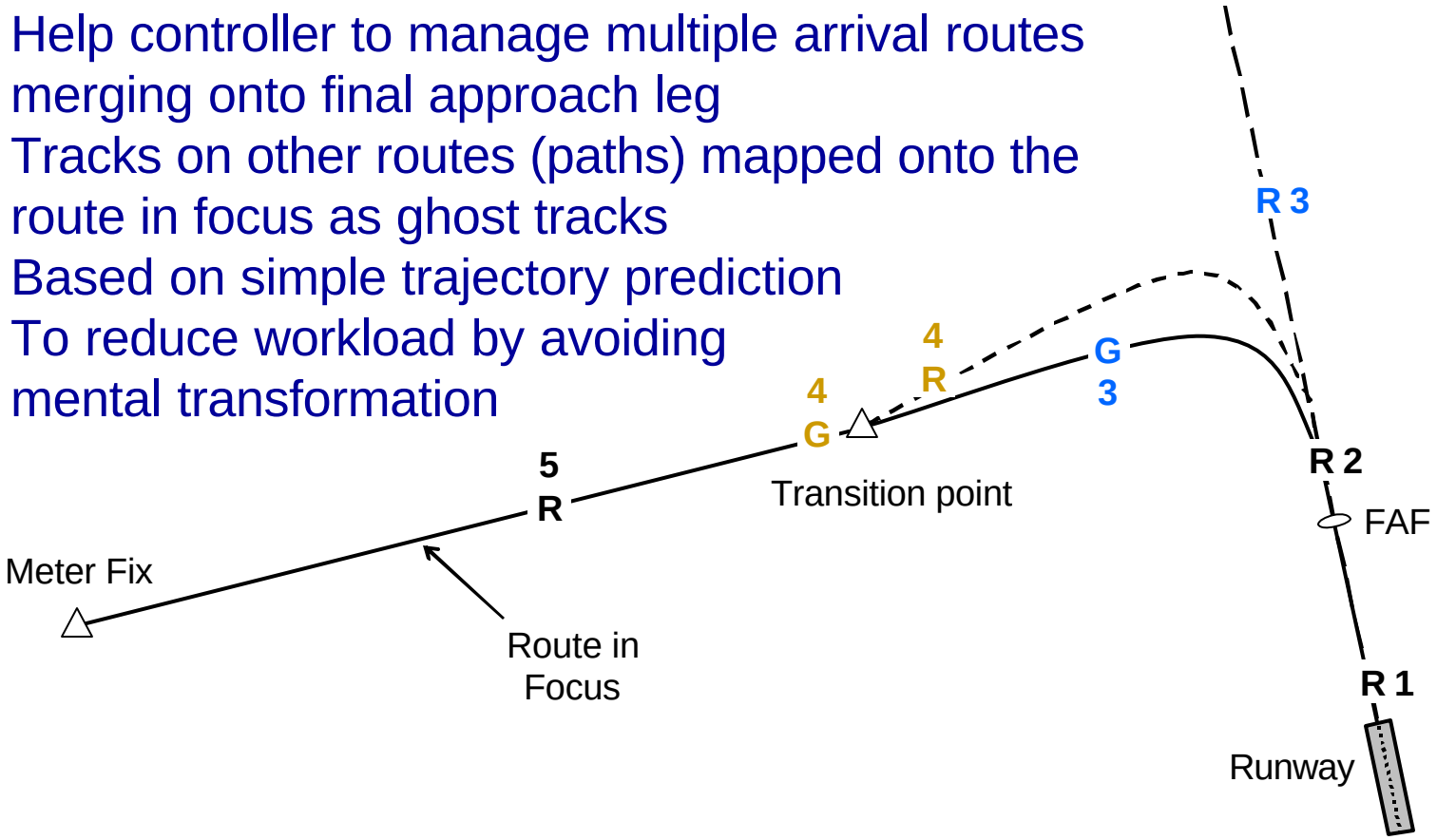
- **Modify CTAS Time Line Tool for Spacing and Monitoring**
  - Originally designed to improve controller situation awareness
  - At the transition waypoint prior to TOD where path stretch occurs
    - Scheduled time of arrival based on aircraft type and winds to satisfy initial separation at TOD
    - Alert controller the necessity of lateral path stretch
  - At runway threshold
    - Scheduled time of arrival based on wake vortex separation matrix
    - Alert controller for possible separation violation



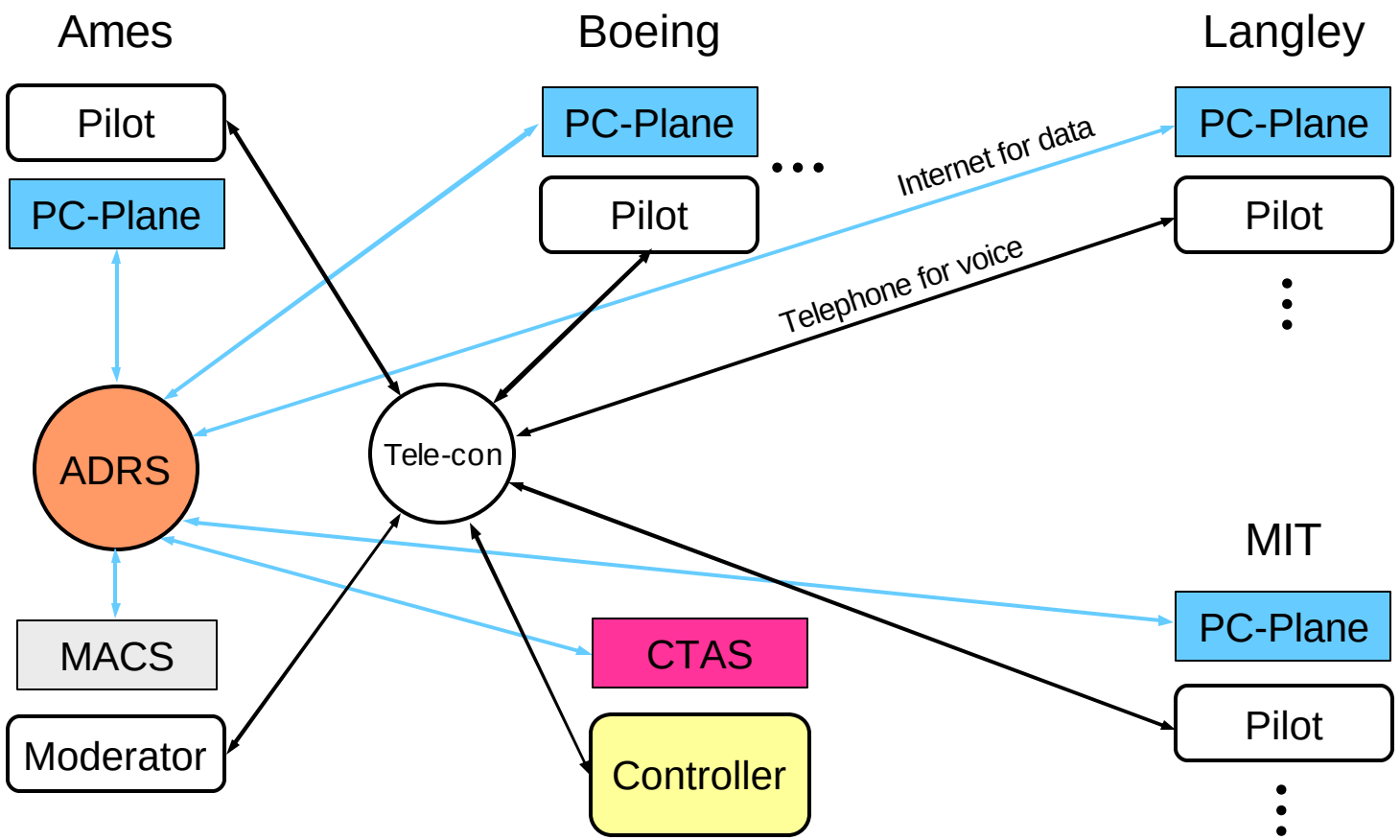
TMA Time Line Example
Modified from NASA Ames

Automation Design - Ghost Display

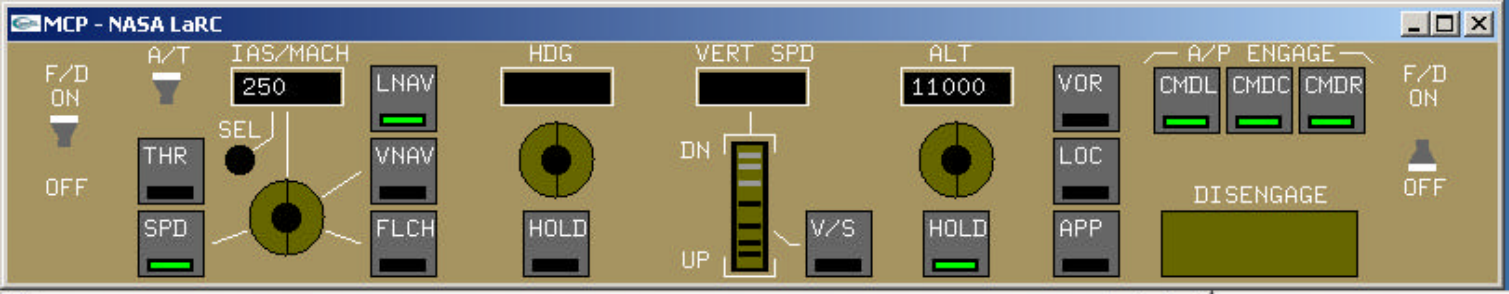
- **Develop a Ghost Display to Reduce Workload**
  - Help controller to manage multiple arrival routes merging onto final approach leg
  - Tracks on other routes (paths) mapped onto the route in focus as ghost tracks
  - Based on simple trajectory prediction
  - To reduce workload by avoiding mental transformation



Air-Ground Simulation Architecture



After NASA air-ground distributed simulation system


MCP - NASA LaRC
F/D ON
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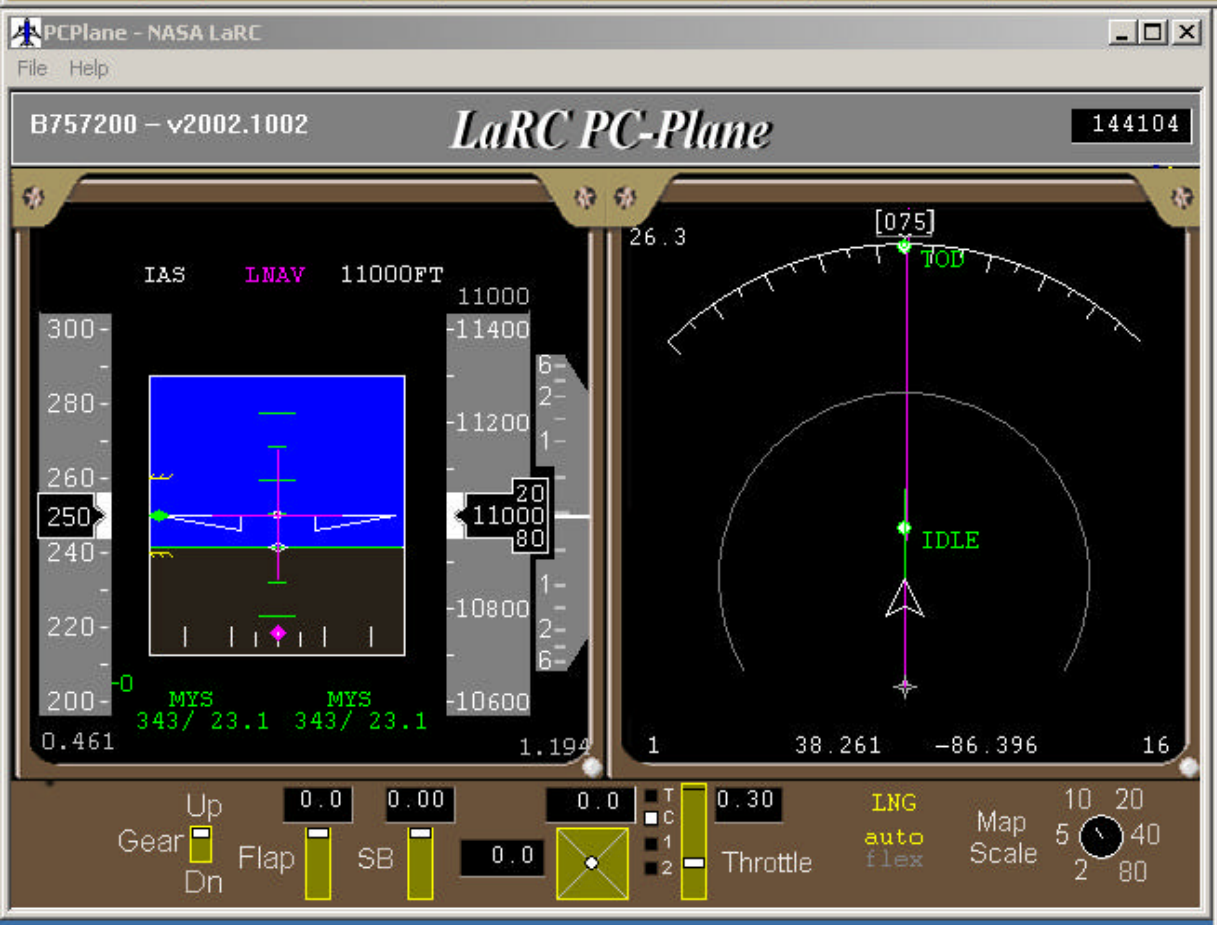
PCPlane - NASA LaRC
File Help
B757200 – v2002.1002
LaRC PC-Plane
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MYS 343/ 23.1
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Map Scale
10 20
5 40
2 80

Control Display Unit
LOW NOISE GUIDANCE 1/2
ALTITUDE ERROR
0
STATUS
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CAS TARGET
250
ENERGY ERROR
-5
TIME TO RWY / ETA
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LEG00
LEG02
LEGRE
MIT103 : BAMBE/13R : FL67

Experiment Design

- **Hypotheses**
  - Air traffic control for low noise approach is more difficult for controller
  - Automation tools – trajectory prediction, time-line, and ghost display – help to improve performance and reduce workload
- **Subjects**
  - Controllers
    - Professional controllers
    - Perform air traffic control tasks
      - Space aircraft for low noise approach
      - Merge aircraft onto final
  - Pilots
    - Trained pilots or student pilots
    - Serve as agents to generate realistic traffic scenarios
    - Execute controller's commands

Experiment Design

Independent Variables

- Factors of Interest
  - Three (3) treatments of procedure and automation combinations
    - Conventional approach
    - Low noise without new tools
    - Low noise with new tools - time line and ghost display
  - Incoming traffic flow
    - Traffic flow rate (number of aircraft per hour), fixed for initial study
    - Variation of separation or time of arrival at meter fix, fixed for initial study
    - Aircraft mix, fixed for initial study, assume all FMS equipped
  - Winds uncertainty
    - Fixed for initial study
- Nuisance factors
  - Controllers vary in skills and experience, and personal preference
  - Pilots vary in skills and experience

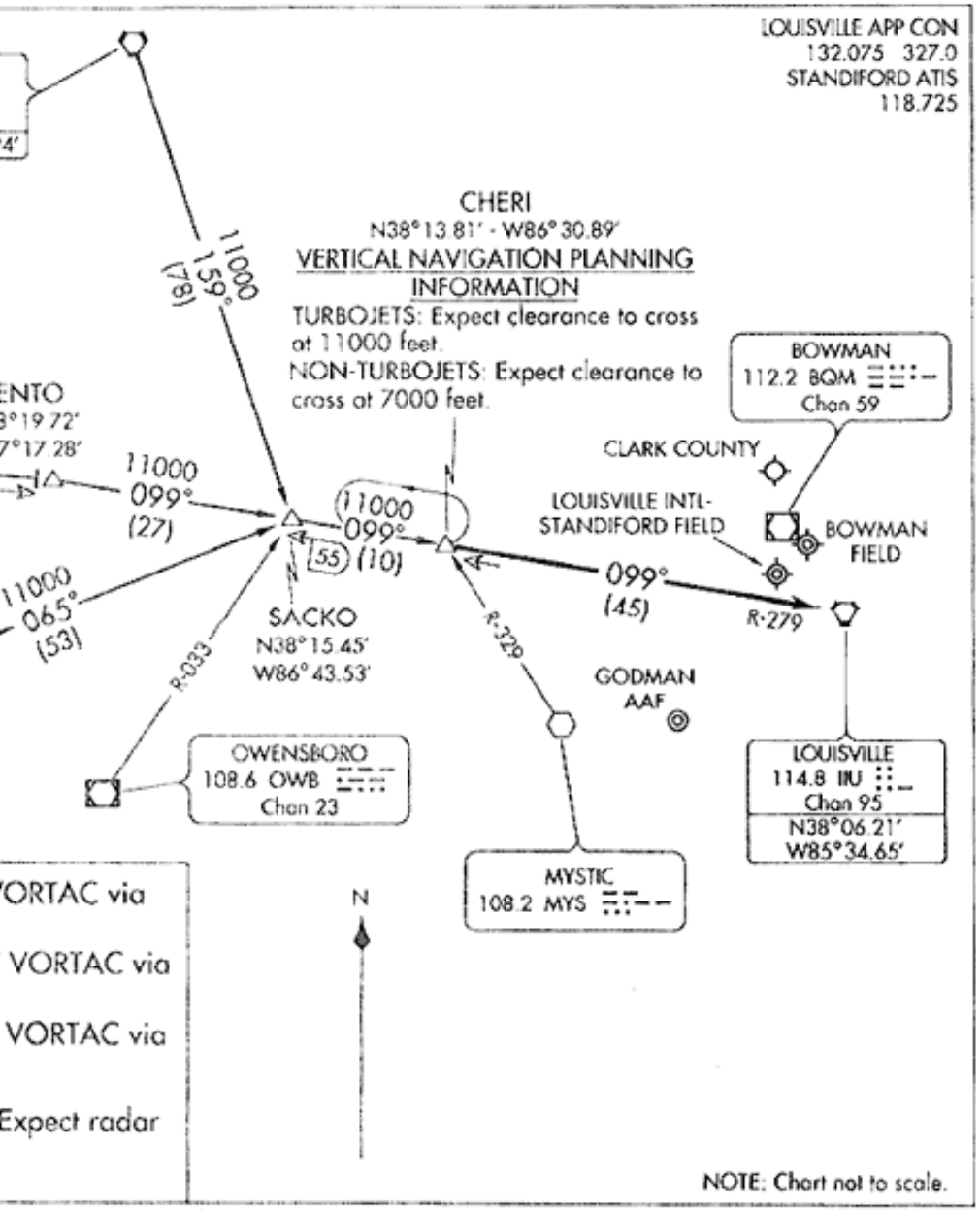
Experiment Design

Dependent Variables

- Safety – number of separation violations
- Efficiency – actual flight time from meter fix to runway threshold
- Controller strategy – speed adjustment and flight path vectoring
- Workload – post test subjective Cooper-Harper type scale for each of the three treatment
- Situation Awareness – subjective Cooper-Harper type scale for each of the two automation tools
- Subjective preferences and acceptability - questionnaire

Test Plan

- Within subject treatment test design
- Use at least 6 controllers
- Randomly assign predefined order of treatments for each subject
- Randomly assign pilot to each airplane



EC-2, 23 JAN 2003

LOUISVILLE, KENTUCKY

AL-239 (FAA)

ILS RWY 17R

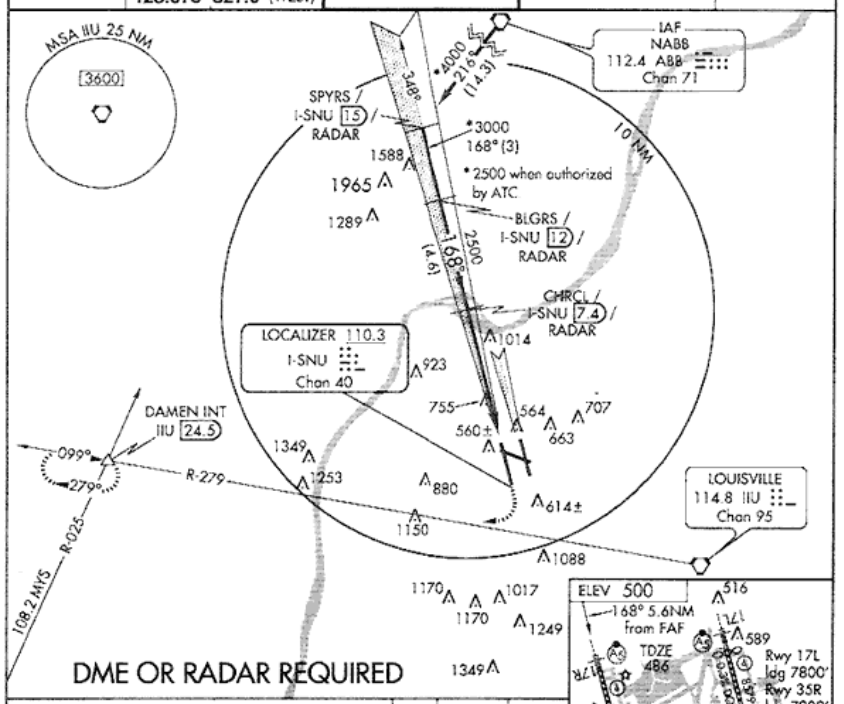
LOUISVILLE INTL-STANDIFORD FIELD (SDF)

LOC/DME I-SNU	APP CRS	Rwy Idg	10000
110.3	168°	TDZE	486
Chan 40		Apt Elev	500

MALSR

MISSED APPROACH: Climb to 1600 then climbing right turn to 3000 via heading 230° and IIU VORTAC R-279 to DAMEN Int and hold

ATIS	LOUISVILLE APP CON	LOUISVILLE TOWER	GND CON	CLNC DEL
118.725	132.075 327.0 (EAST) 123.675 327.0 (WEST)	124.2 257.8	121.7 348.6	126.1



CATEGORY	A	B	C	D
S-ILS 17R	686/24 200 (200-½)			
S-LOC 17R	1320/24 834 (900-½)	1320/40 834 (900-¾)	1320-2 834 (900-2)	1320-2⅛ 834 (900-2¼)
CIRCLING	1320-1 820 (900-1)	1320-1¼ 820 (900-1¼)	1320-2½ 820 (900-2½)	1320-2¾ 820 (900-2¾)

FAF to MAP 5.6 NM

Knots	60	90	120	150	180
Min:Sec	5:36	3:44	2:48	2:14	1:52

LOUISVILLE, KENTUCKY
Orig-A 01361

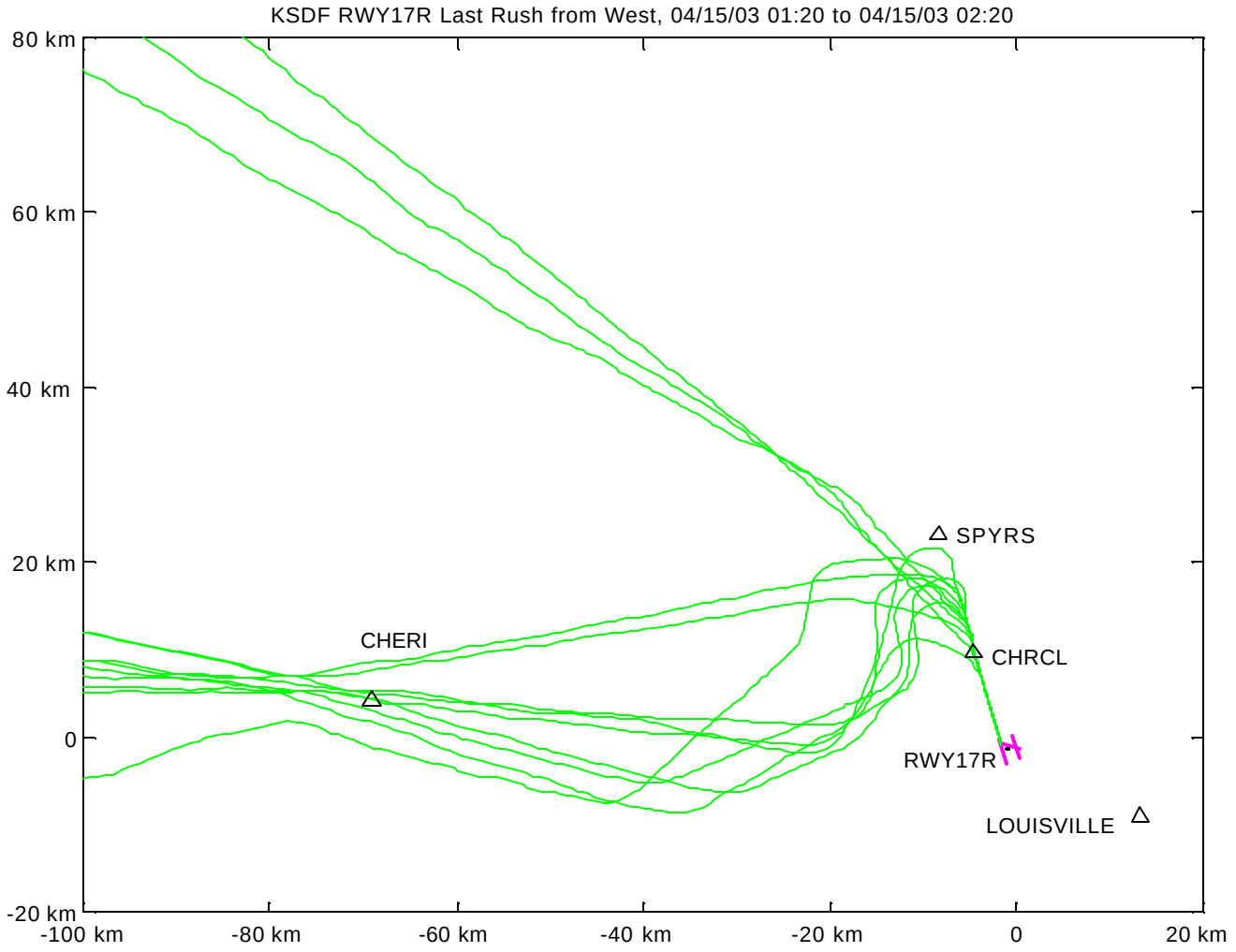
38°10'N-85°44'W

LOUISVILLE INTL-STANDIFORD FIELD (SDF)

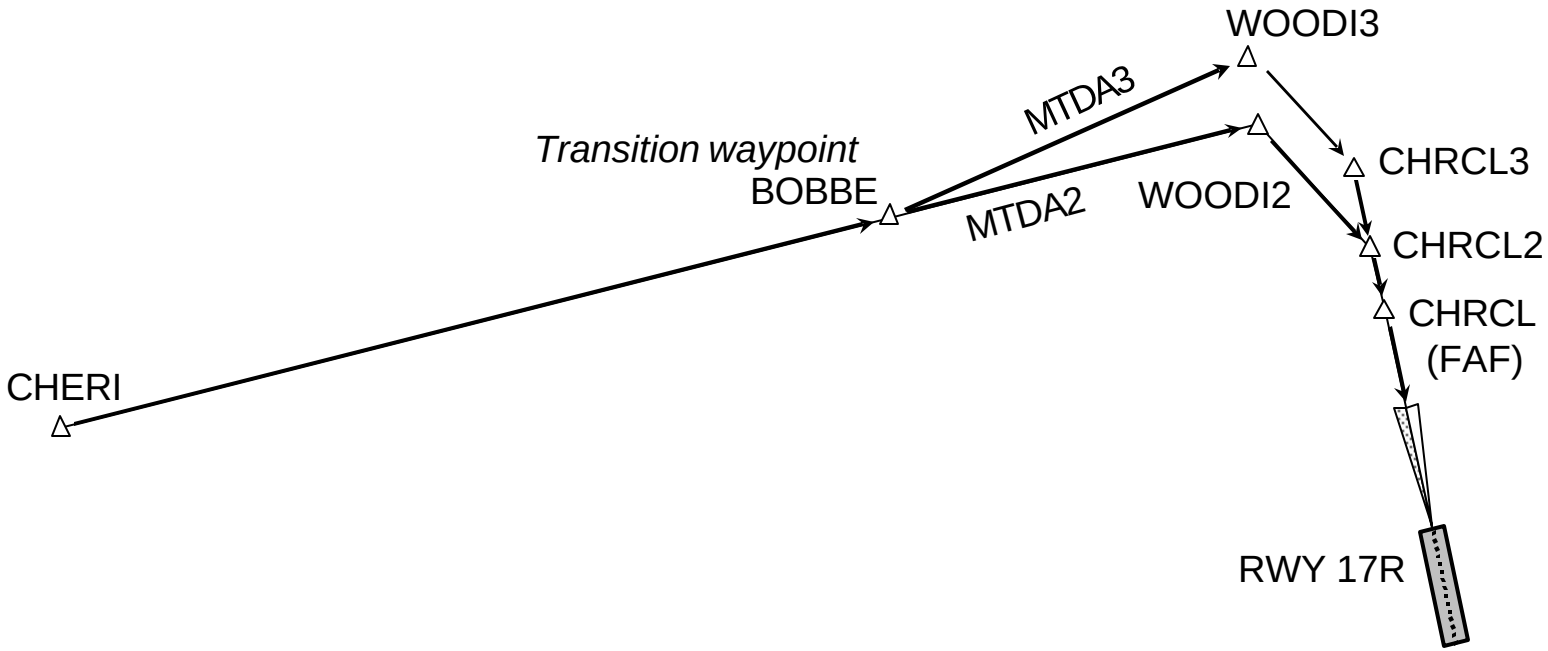
ILS RWY 17R

SE-1, 23 JAN 2003

Last Block of KSDF Night Arrival



Low Noise Arrival Chart



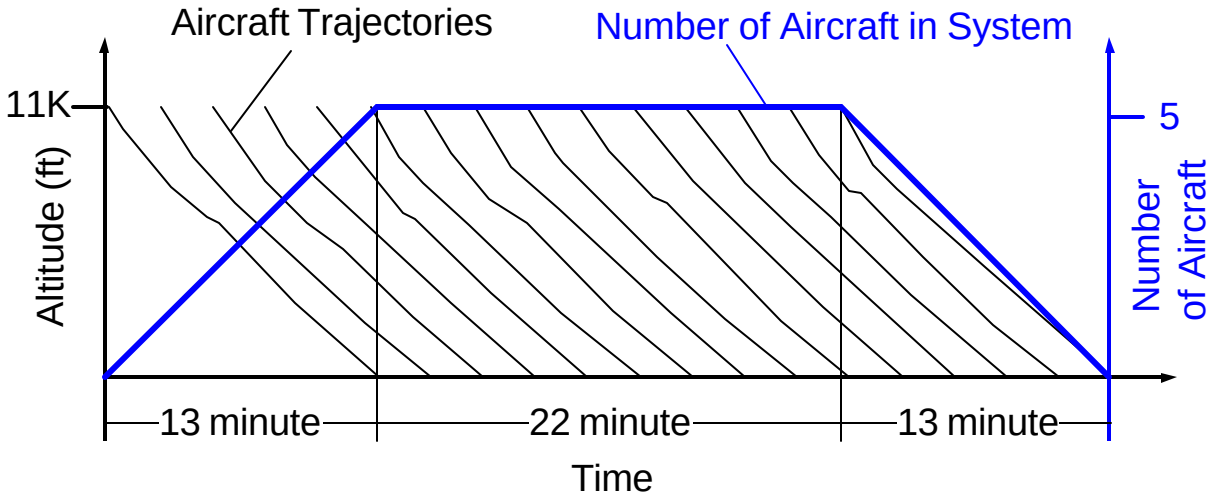
Scenario Generation

- **Target Application**
  - UPS KSDF night arrival traffic flow landing to the south on runway 17R
- **Traffic flow generation**
  - Use recorded Passur flight track data (update rate 4.6 seconds)
  - Modulated as incoming stream from west via CHERI
  - With occasional straight in traffic from north via SPYRS
  - Consists of only B767 and B757 aircraft
  - Preserve traffic flow density (~33 aircraft per hour for two runways, 24 per hour for 17R, which is moderate)
  - Preserve aircraft mix and time of arrival variation at meter fix
- **Winds**
  - Annual average wind is used for initial study

Scenario Generation

Scenario Length

- Each scenario lasts about 50 minutes
- Assuming a traffic flow of 24 aircraft per runway per hour
  - Flight time is about 13 minutes from meter fix
  - Controller handles 15 aircraft in total
  - Controller works under peak flow for about 22 minutes



Experiment Protocol

- **Trial Experiment**
  - Develop and fine tune procedures and clearance phraseology
  - Train pilots to achieve consistent low noise profile
  - Controller's task performed by researchers
- **Controller Briefing and Training**
  - Briefing on low noise procedures
  - Training runs performed with two aircraft
  - Controller fully mast the control task and automation tools before formal experiment
- **Formal Experiment and Data Analysis**
  - To start late 03 or early 04 if everything goes well
  - Moderator coordinates pilots to generate traffic flow
  - Actual time of arrival of each aircraft at meter fix generated randomly with variance depicting the real world traffic flow

Future Work

- **Explore Different Conditions**
  - Higher traffic
  - Different levels of time of arrival variations at meter fix
  - Include aircraft performing conventional approach
  - Varying Wind conditions
- **Explore Other Operation Concepts**
  - LNAV flight path interruption and recovery
  - Operations with data link
    - Real time airborne trajectory computation with intent ADS-B downlink
    - Ground trajectory synthesis with procedure uplink
    - Are additional noise benefit worth the effort? Reducing system safety?
- **We hope the distributed simulation would help probable flight test in the future**

Acknowledgement

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Nhut Tan Ho & Katherine Zou of MIT,
Everett Palmer & Len Tobias of NASA Ames,
Tod Lewis & Dave Williams NASA Langley
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